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1 Introduction

Autonomous cars are currently a topic of great interest. Around the world the biggest private companies or governments initiatives are developing self-driving vehicles (uber, google, britol car citations), competing for new emerging market. Each company focuses efforts in different direction. The companies are either trying to develope an all-round car that could perform in both city and on highways or restrict the usage to particular types of roads (tesla). Or anyhing in between. The most significant commercial initiatives include Google driverless car, Tesla, Uber (). Goverment founded initiatives include Venturer and ...

Background of the problem, context of the research, reasons why the study was carried out, significance of the study

Many experts around the world are trying to predict how autonomous cars will influence our lives. One of the questions is how the traffic itself will change. Most of the experts agree that in the next decades we will observe gradual process of increasing the share of autonomous cars on our roads. In that time human-driven cars and self driving cars will have to successfully interact with each other. According to predictions the fully automated traffic will become reality only around year 2060 or year 2040 in more optimistic predictions and first commercial autonomous cars are already appearing on the roads (singapore, uber). Although there are numerous studies on many aspect of autonomous driving as well as on interactions between regular cars in all-human-traffic there is little research on interactions between these two types of vehicles and all its consequences.

A statement of the problem to be addressed

The focus of this research is to investigate how autonomous cars will influence traffic itself and how human and autonomous cars will interact with each other.

clear and succinct statement of research questions, aims and objectives.

The main aim of the research was trying to predict what will happen when autonomous cars are introduced to the traffic. Results obtained were analysed from the point of view to traffic parameters such as velocities, densities, congestion and from the point of view how individual drivers reacted differently when autonomous vehicle was encountered.

The main objective of the project was to create a an on-line traffic simulation that would allow to connect multiple people together at the same time. People were asked to drive a car

How scope was reduced The original scope of the project included also in-silico implementation that would be using remotely controlled "slot-cars". It was believed that that physical model would have features that could not be accounted for or predicted in computer simulation. It was estimated for around 50% of implementation effort. However, the final version of the project the physical model was not implemented. After the project went into development the advantages of creating a physical model appeared less and less attractive. Especially compared to the cost of implementation. Original idea assumed using digital slot-car set with cars and track, as well as computer vision to track vehicles on the track and live video streaming to multiple computers. After more careful consideration the benefits of implementing above described would be very minor or none. In addition to this, implementing the computer simulation consumed more time that

estimated.

It has to be admitted that scope was drastically limited in terms of implementation effort. It did not, however, have much impact on the quality of the research and conclusions. One would even venture to say that project should only consist of computer simulation even if more time and resources were allowed for project execution.

A road map of what is going to be discussed The project consisted of three main parts. First one was software development. This accounted for around 50% of all efforts. The chapter on Research Methodology is mostly dedicated to this. Software section is divided into most significant components that include the design of simulation master, design of client's interface and vehicle's control. The chapter on research methodology also describes how communication between machines was established and the algorithm behind autonomous vehicles. Although these two aspects were integral parts of the software it was decided to write about them separately. It is due to the significance and universality of communication solution and autonomous car algorithm. Most of decisions made throughout the development stage were aimed for successful experiment execution. The design of the experiment and how it was eventually conducted are described at the of Research Methodology chapter.

The Research Methodology chapter is preceded with in-depth chapter describing literature relevant to the project.

The data obtained during the experiment was described in Findings and Results chapter. This chapter also talks about different ways in which data was analysed.

The last two closing chapters discuss the results of the experiment, at-

tempt to draw conclusions and generalize findings in wider context.

2 Literature review

There is plenty of literature dedicated to autonomous cars.

2.1 Current and future development of autonomous cars

The prime examples of the most recent achievements in the field of autonomous cars are visible through cutting-edge commercial projects such as google self driving car, uber's and ¡shanghai something¿. Google is probably the most experienced player as the development of it's self driving car started already in the year 2009 (google self driving car website). Google's car is classified as level 3 in automated vehicle classification system proposed by NHTSA in 2013 (http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+T which is described as "Limited Self-Driving Automation". The car takes full control over all safety-critical functions but at certain times driver can be asked to retake control.

List of trials on autonomous vehicles is here: (Parkin et al. 2016) googel, volvo, audi, singapore, and add uber

- also say about history of autonomous cars

Vehicle classified at level 4 would have to

Uber is a relatively new player in the business of autonomous cars.

Write about audi autonomous racing car

In the near future we should be able to see more and more autonomous vehicles on the roads. The report released by UK Department of Transport titled "The Pathway to Driverless Cars Summary report and action plan" states that government recognises the benefits of autonomous vehicles and

is undertaking actions to aid the development of technologies and law that would allow to bring driver less cars on public roads.

2.2 Implications of autonomous cars revolution

Experts around the world argue about the consequences of introducing self-driving cars. The report by UK Department of Transport "The Pathway to Driverless Cars" summarizes some main benefits of heaving autonomous cars. Most important points include significant reduction of time spent in vehicles and largely improved safety. It is stayed that an average driver could save up to 6 working weeks of driving time in a single year. The claim on potential improvements of safety is backed by existing evidence from automated vehicles that are already commercially available. Such vehicles feature level 2 of autonomy and can be capable of emergency braking, lane control or adaptive cruise control. More advanced cars like Tesla S are also able to actively change lanes on a motorway when instructed by driver(link to tesla's manual). Another important benefits include reduced emission and reduced congestion. Vehicles that are connected into one system would be able to drive in the interest of all traffic participants and therefore greatly optimize traffic. A consequence of traffic optimization and overall reduction of Total Kilometers Traveled would be major cost reduction and therefore increased access to vehicles for everyone. (all from link)

link:

On the other hand, it is argued that autonomous vehicles will not be as robust as expected and traffic parameters will, in fact, worsen(**?**).

There are also many other indirect implications. As stated in (Litman 2014) an example will be a family that decides to settle further from the

city because they can productively spend time in the car rather than control the vehicle. In consequence the benefits of faster and more optimized travel will be counteracted by overall increase in demand. Consecutively the traffic parameters will not improve as expected.

Rely heavily on: (Litman 2014)

adittionally:

2.3 Maximum Capacity Theorem

2.4 Conflicts, collisions and interactions on the road

(Parkin et al. 2016)

According to (Contributory factors of reported accidents, Great Britain excel) most accidents are caused by human failure. The main contributory factors are failure to look properly, failure to judge other's person speed or path and driver, carelessness, recklessness or being in a hurry.

(writing about it in the context that autonomous cars can potentially improve these things)

Although the study on conflicts on the road is very complex and hard to quantify according to (Risser 1985) there are numerous factors that contribute to creating conflicts. These factors include excessive speed or poorly adopted speed, too small distance to proceeding car, violations of the right-of-way and many other types of behaviour.

More about interactions in general...

2.5 How people cooperate with autonomous cars

As mentioned in introducing autonomous cars should result in smaller number of accidents. A machine would be free from factors mentioned in previous

chapter.

2.6 Measuring traffic performance

2.7 Autonomous car model

Inteligent driver model etc

gipps

2.8 SUMO

2.9 Communication between machines - maybe

2.10 Experiment design - real world research

Parkin et al. (2016)

3 Research Methodology

Justify the structure of the project. Why the experiment was a key part. Why this was the best option rather than for example use data from some database?...hmmm

3.1 Experiment design and implementation

Justify all major design decisions. Plenty of them! All the actions undertaken to ensure most meaningful results

3.1.1 some other subsections

3.1.2 Data collection

How the experiment was eventually conducted

3.2 Software development

Justify all major design decisions

3.2.1 Simulation master design

3.2.2 Client's interface design

General description Simplifications and yet still accounting for most important parts of the car model

3.2.3 Car control

3.3 Communication between machines

From one point of view this a tightly coupled with software development but the way communication was established doesnt matter from the point of view of software structure. Simply speaking the comms should only meet some requirements derived from the main piece of software and the details of implementation doesnt matter. This was a significant part of the job and its an achievement on its own.

3.4 Autonomous car model

Say why this is important from the point of view of results obtained. Again justify all design decisions

3.5 Experiment design and execution

4 Findings and results

5 Discussion of results

6 Conclusions

References

Litman, T. (2014), 'Autonomous vehicle implementation predictions', *Victoria Transport Policy Institute* **28**.

Parkin, J., Clark, B., Clayton, W., Ricci, M. & Parkhurst, G. (2016), 'Understanding interactions between autonomous vehicles and other road users: A literature review'.

Risser, R. (1985), 'Behavior in traffic conflict situations', *Accident Analysis & Prevention* **17**(2), 179–197.